Annual Project Summary
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Calculation and validation of a probabilistic seismic hazard assessment for the urban area of Evansville incorporating site effects

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Prof. Jennifer S. Haase, Prof. Robert L. Nowack and Yoon Seok Choi
Dept. of Earth & Atmos. Sci., Purdue University
550 Stadium Mall Dr
West Lafayette, IN 47907-2051
765-494-1643; 765-496-1210; jhaase@purdue.edu

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Non-technical Summary

The central US has a low rate of seismicity, but because of the occurrence of past earthquakes such as the 1811-1812 New Madrid events as well as prehistoric events in the Wabash Valley Fault Zone, there is a significant seismic hazard. Evansville, Indiana, is one of the closest large urban areas to both the New Madrid and Wabash Valley fault zones. For this reason, it has been targeted as a priority region for urban seismic hazard assessment and surficial geologic mapping, along with Memphis, TN, and St. Louis, MO. The probabilistic seismic hazard methodology that will be used in the Evansville, IN, region incorporates information on the depth and properties of near surface sediments and their uncertainties. The work is taking place in coordination with surficial geologic mapping efforts on the part of the USGS and state geological surveys. A preliminary version of the probabilistic seismic hazard map has been calculated using the existing data available as of October 2005. The hazard calculation will be updated as the final version of the mapping products become available.

Investigations undertaken

This project is designed to produce a probabilistic seismic hazard map for the nine quadrangle region surrounding Evansville that takes into account amplification due to near surface geologic structure. All available data are compiled from past seismic refraction studies, well logs, geotechnical borings, and cone penetrometer test (CPT) data to characterize the material properties at relatively high resolution. A methodology has been developed to convert information on lithology from bore logs to approximate velocities, and the uncertainties in this process have been characterized for units north of the Ohio River. Data has been recently acquired south of the Ohio River in Kentucky, which is being compared with the Indiana data to validate the methodology. Currently, the main investigation is performing the preliminary site amplification and probabilistic seismic hazard calculation using simple soil shear wave velocity model. The objective of the preliminary calculations are to demonstrate whether or not there is a clear correspondence between the properties of the bedrock valley fill and the amplification.

This would present a promising perspective for extending the analysis to surrounding regions based on the evidence from depositional history of the sediments on the floodplain, terraces, and uplands. The methodology for subsurface characterization that includes a shear wave velocity model and the depth to bedrock is being developed with compiled data sets. A preliminary model has been developed and the amplification and probabilistic seismic hazard calculation have been carried out with this data. The input data set will be augmented in the spring quarter at which time the calculations will be redone for a final model.

The primary remaining tasks include:

1) Compile and collect more available data sets within Evansville area
2) Calculate site amplification with the improved soil profile model and apply it in the probabilistic seismic hazard calculation

Results

1) Local geology and CPT soil profile data collected by the USGS in Nov, 2003

The CPT data are first used to classify the soils and generate the soil stratigraphy, and then each layer is analyzed for site-amplification. The soil profiles (Figure 1) show that there are distinctively different soil properties in the four geologic regions.

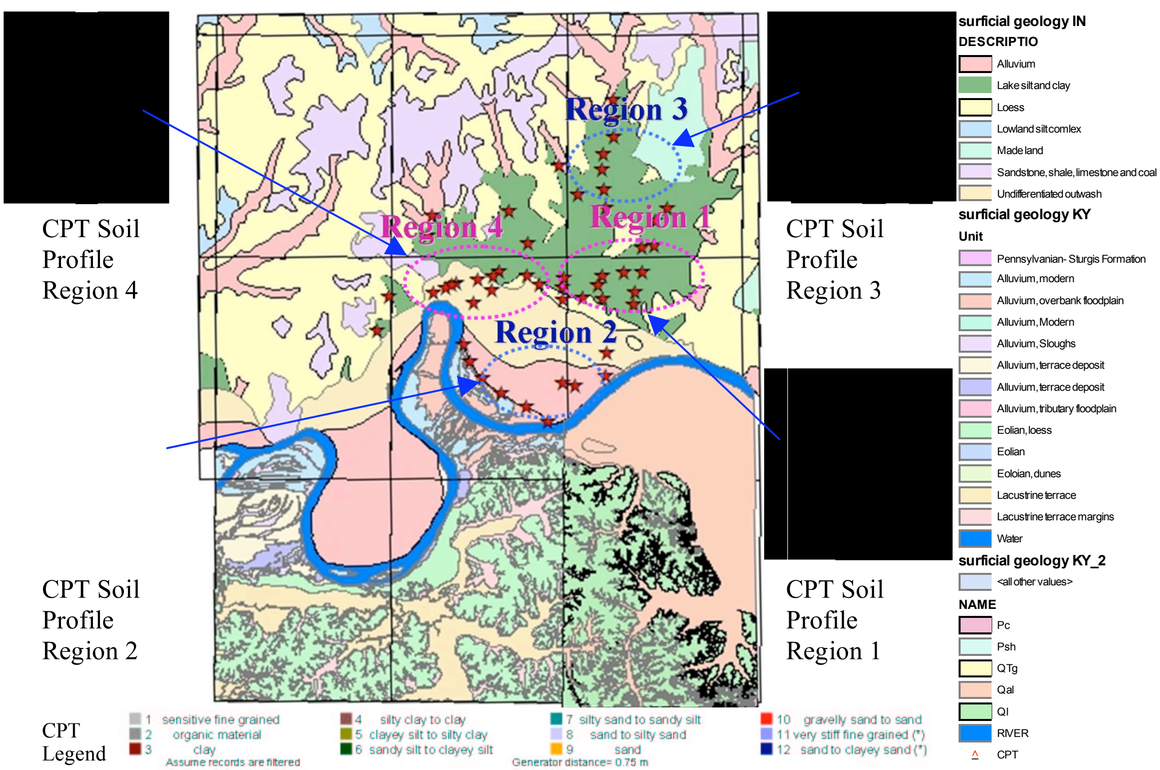


Figure 1. Map of surficial geology and soil profiles from the Cone Penetration Test Data from the four different regions, ordered west to east (south to north for region 3).

The United States Geological Survey, the Central US Earthquake Consortium (CUSEC) geologists and the state geological surveys in Indiana, Illinois and Kentucky are currently in the process of mapping the surficial geology in more detail and compiling subsurface data for information on the near surface structure of the unconsolidated sediments.

2) Available datasets and depth to bedrock

The depth to bedrock at each gridded point in the domain is needed for the site amplification and response calculation. Therefore, the depth is interpolated from water well logs, seismic data and geotechnical boreholes (Figure 2b). All available and collected datasets (Figure 2a) include:

- 48 CPT profile data collected by the USGS
- 33 borehole S-wave velocity profiles [Eggert et al., 1994]
- 570 new SPT blow count data at over 60 geotechnical boring sites
- IGS Database of over 230 Seismic refraction profiles
- KGS S-wave refraction profiles [CUSEC final report 2004]
- Indiana Geological Survey iLITH GIS database of approximately 900 water well logs
- Bedrock elevation points [Ron Counts, KGS]

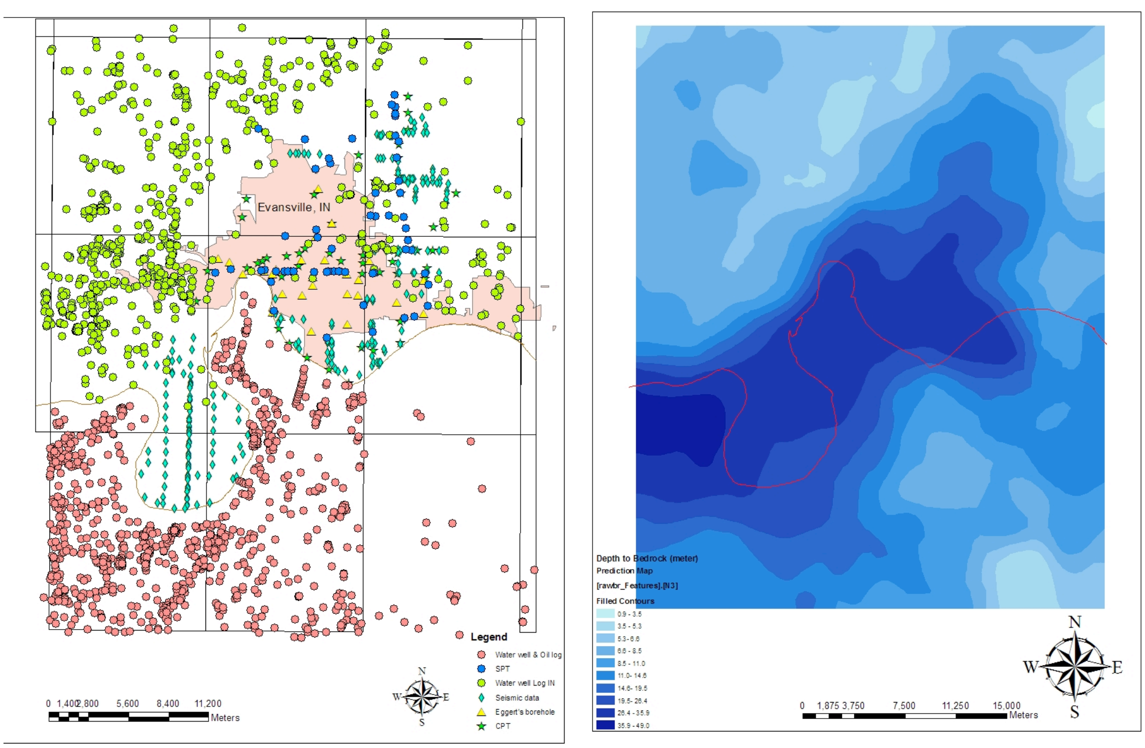


Figure 2a. Locations of observations (left), 2b. Depth to bedrock contour (right)

3) Shear wave velocity

Shear wave velocity CPT measurements are correlated with soil type (Figure 3). Limited CPT and borehole shear wave velocity measurements are available in the study region. Relatively dense sampling of water well and geotechnical bore log information is available with lithologic descriptions of the soils, however, distinct laterally extensive units do not exist in this area. We use the shear wave velocity observations to determine a relationship between shear wave velocity and lithology. Though the profiles do not appear to have a significant dependence on surficial geology, there is some dependence on lithology. The mean value for units containing sand is 255.0 ± 43.5 (m/s) and for units containing clay is 205.7 ± 32.3 (m/s), which are statistically distinct (Figure 4).

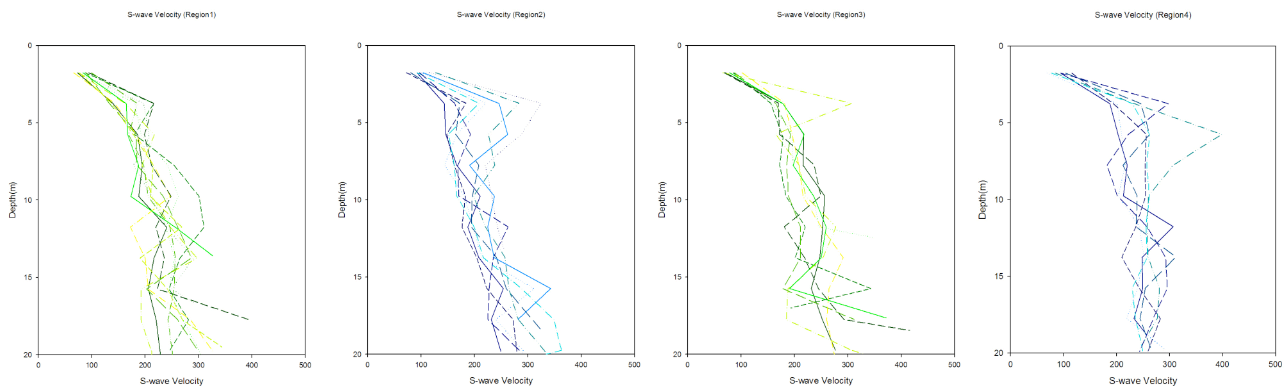


Figure 3. Shear wave velocity profiles from the cone penetration test data from the four different regions

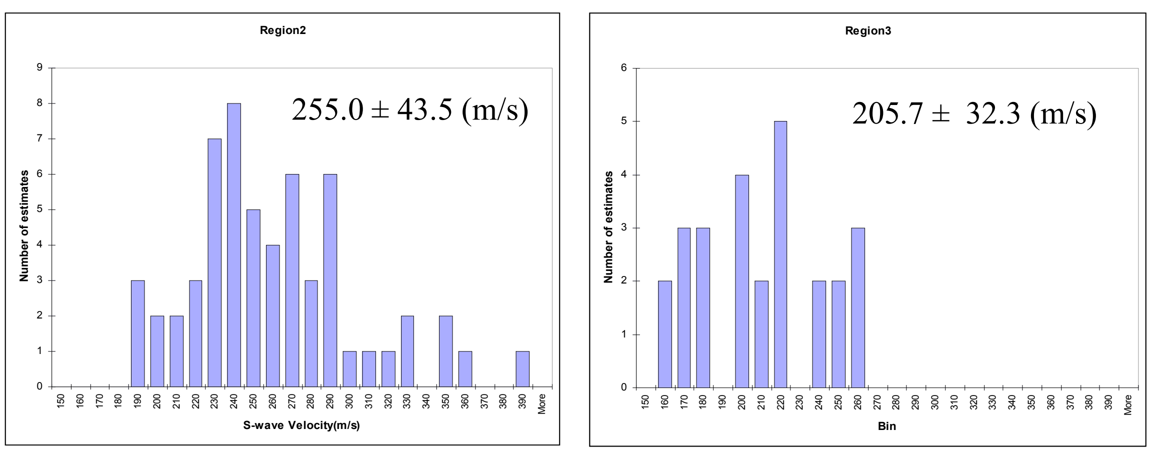
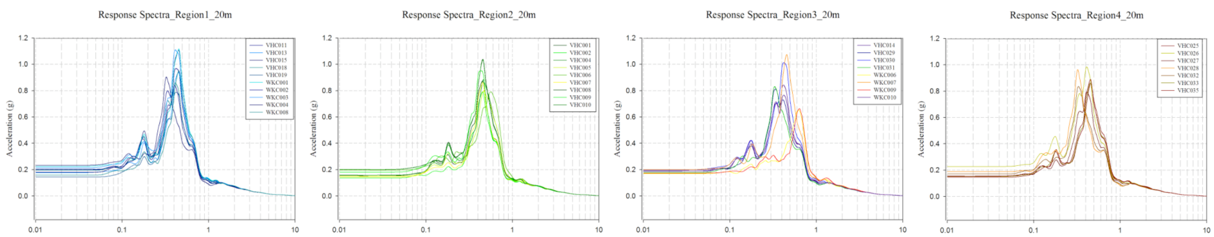


Figure 4. Shear wave velocity histograms for the sand and clay units in the CPT profiles

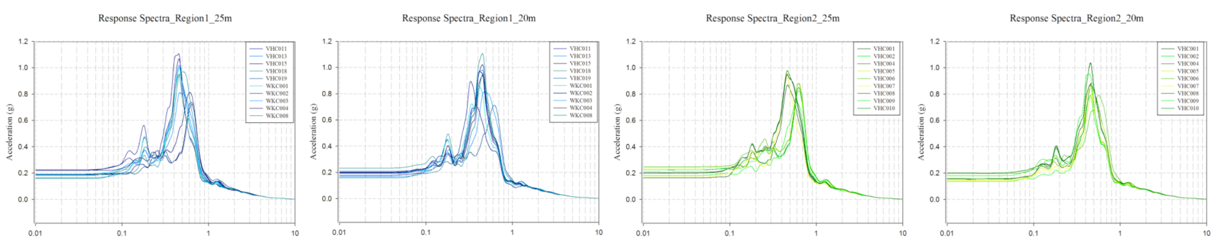
4) Site response spectrum in different geologic region

The response spectrum was calculated for each soil profile assuming a fixed depth to bedrock of 20 meters using a quasi-linear frequency domain summation approach (SHAKE 91, Schnabel et al. 1972) (Figure 5). The variation in peak ground acceleration for profiles located within a single region is as large or larger than the variation among the 4 regions. Therefore assuming a typical seismic profile for each surface geological unit does not produce a large variation in seismic velocity over the region. The response was calculated for each region assuming two different values for the depth to bedrock, 20 m and 25 m. The variation in response due to the 5 m depth difference is larger than the effect of the velocity variations (Figure 6).



Region 1 Region 2 Region 3 Region 4

Figure 5. Response spectra for the 4 regions with a fixed soil depth of 20m



Region 1_25m Region 1_20m Region 2_25m Region 2_20m

Figure 6. Response spectra for region 1 velocities with a soil depth of 20m and 25 m

5) Site amplification and Probabilistic Seismic Hazard Map

The site amplification at each of 1482 grid points of the domain was calculated in the following manner. 1000 randomizations of the profile were created that have the statistical variation corresponding to the standard deviation of the profile bedrock depth and soil shear wave velocity. The response and amplification were calculated for each profile and the amplification values were averaged and the log standard deviation was determined. The calculation was done using input ground motion levels from 0.05g to .5 g. The result for 0.05g input ground motion is shown in Figure 7. The calculation shows a distinct amplification for regions where the depth to bedrock coincides with that which produces a resonant frequency. At 5 Hz amplifications are roughly 2-3 times in the floodplain of the Ohio River. The calculation follows the methodology used for creating the urban seismic hazard maps for Memphis (Cramer et al, 2003).

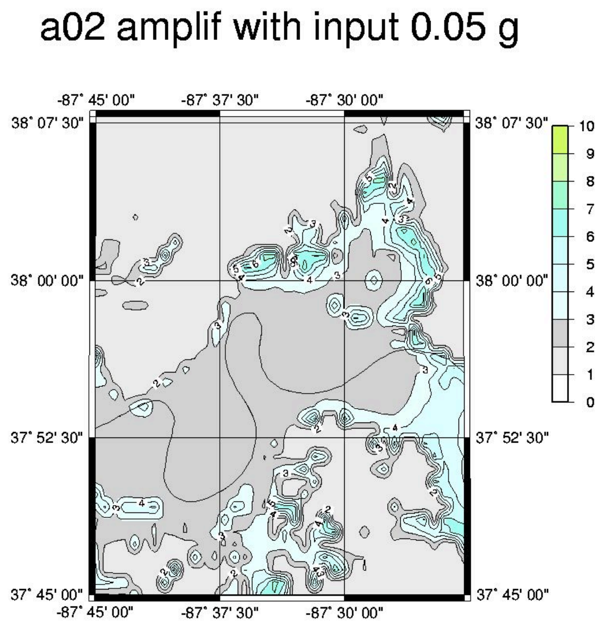


Figure 7. An example of the site amplification calculation (0.2 sec S.A. with 0.05g input ground motion)

Given the amplification due to site response and its associated uncertainty, the attenuation curves for ground motion levels were modified for the calculation of the probabilistic seismic hazard. The hazard calculation takes into account specific characteristic earthquake sources such as the New Madrid fault zone as well as the hazard due to distributed seismicity in the central US region. The methodology follows that of Frankel (1996,2002) for the national seismic hazard maps for the central and eastern US, with the modification to take into account the near surface effects as in Cramer (2003). Figure 8 shows one example of the probabilistic hazard map at 5 Hz frequency. The contours indicate the maximum ground acceleration level that has 2% probability of being exceeded in the next 50 years. 5Hz accelerations in some cases are shown here to be quite high, greater than 1.0 g in some localized areas. This map is preliminary and will be recalculated after a final velocity model has been developed that takes into account the latest observations and mapping products available.

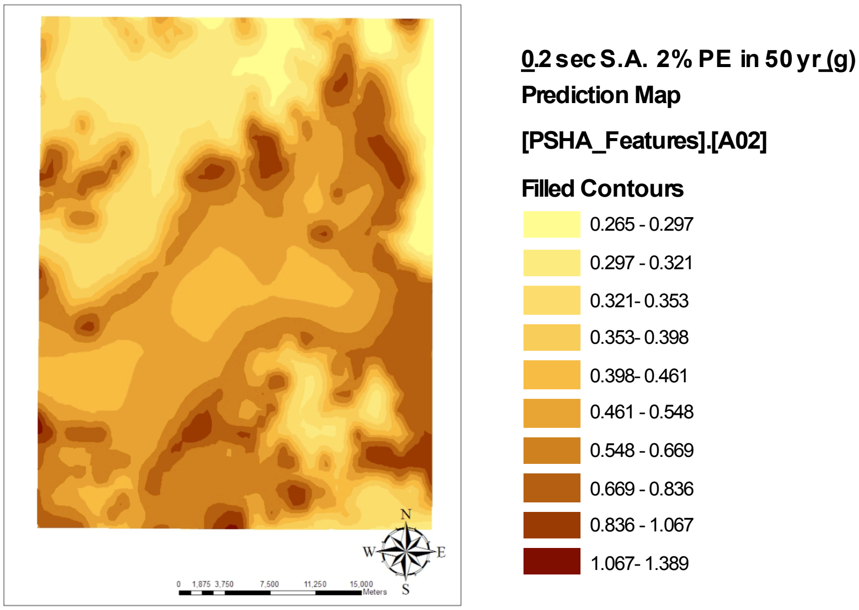


Figure 8. Probabilistic Seismic Hazard Map (0.2 sec S.A. 2% PE in 50 yr)

Reports Published

No reports have been published.

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